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# Saturation Effect of Plastic Scintillators\*

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It is known that for high energy losses the light output from a scintillating fluor is not proportional to the energy loss of the irradiating particle passing through it in the cases of organic crystals<sup>1-7</sup> and liquids,<sup>8</sup> and to a smaller extent, in the case of inorganic crystals.<sup>9</sup> Recently we made some measurements of this saturation effect in plastic scintillators and in phenylcyclohexane solution and in a NaI crystal making use of the negative pion beam and the outside proton beam of the Chicago cyclotron. The plastic samples were wrapped with 0.076-mm thick aluminum foil except for the end attached to a 5819 photomultiplier. Two scintillators were placed parallel to each other and perpendicular to the direction of the beam used. The output pulse of one phototube triggered the sweep of a synchroscope whose vertical plates were connected to the output of the second tube. The output pulse of the second tube was (a) observed visually and (b) recorded photographically with a specially designed camera. The two sets (a) and (b) of observations agreed within experimental errors. Absorbers of copper plates were placed between the scintillators to obtain particles of various energies. Calibration readings with Compton electrons of minimum ionization from the 1.3-Mev  $\gamma$ -rays of a  $\text{Co}^{60}$  source were intermittently made during the run.

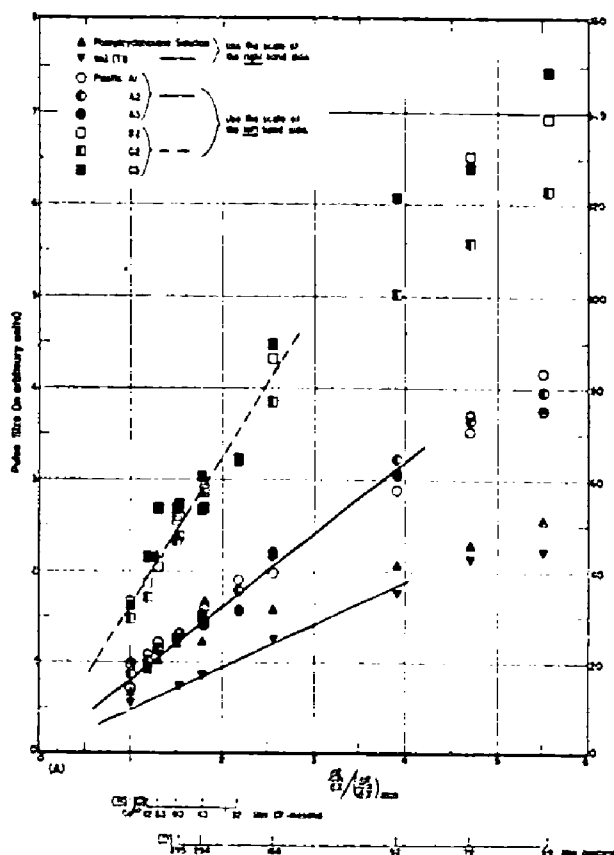


FIG. 1. Variation of light output from the scintillators with energy loss. The ordinate gives the pulse size (in arbitrary units) which is proportional to the light output. The abscissa gives the energy loss in the scintillators. The scale in row (A) represents the energy loss in units of the loss at minimum ionization. (B) refers to measurements with a  $\text{Co}^{60}$  source. Row (C) gives the energies of the pions in Mev corresponding to the energy losses represented in (A) and the scale in row (D) shows the proton energies corresponding to (A).

TABLE I. Pulse sizes (in the same arbitrary units as used in Fig. 1) from plastics irradiated with  $\text{Co}^{60}$  and Po sources.

Plastic scintillator	Specifications	Pulse size observed with $\text{Co}^{60}$ source	Pulse size observed with Po source	Ratio of pulse size with $\text{Co}^{60}$ to pulse size with Po
A1	2% anthracene in polystyrene	0.89	0.50	0.55
A2	3% anthracene in polystyrene	0.86	0.50	0.55
A3	5% anthracene in polystyrene	0.97	0.53	0.55
B2	2% <i>p</i> -terphenyl in polystyrene	1.65	0.82	0.50
C2	2% <i>p</i> -terphenyl +0.03% diphenylhexatriene in polystyrene	1.52	0.92	0.54
C3	4% <i>p</i> -terphenyl +0.03% diphenylhexatriene in polystyrene	2.03	1.05	0.51

Figure 1 shows the variation of the light output from the scintillators vs energy loss. The phenylcyclohexane solution (containing 0.3 percent *p*-terphenyl and 0.001 percent diphenylhexatriene) was 3.4 cm in diameter and 3.4 cm in length. The NaI (Ti activated) crystal was 1.25-in. high, 2.25-in. wide and 0.5 in. in thickness. All the plastic samples were 1-in. square and 5-mm thick. The path length of the mesons and protons through the plastics was 0.5 mm. The specifications of the various plastics and the results obtained with the  $\text{Co}^{60}$  source and with the 5.3-Mev  $\alpha$ -particles from a Po source are given in Table I.

We can make the following remarks concerning the experimental results shown in Fig. 1 and in Table I. Since it is known that in the case of small specimens being irradiated with electrons,<sup>1</sup> NaI(Tl) gives linear response at energy losses well beyond the range covered by the present experiment, the apparent deviation from linear response above about 4 times minimum ionization loss, as demonstrated in Fig. 1, is most probably due to the inhomogeneity of the proton beam and its straggling in passing through the copper absorbers and the geometrical arrangement adopted here. It is to be noted that the *p*-terphenyl in polystyrene plastic gives a reasonably linear response up to about 3 times minimum ionization loss, and the anthracene in polystyrene gives linear response up to at least 4 times minimum loss. The variation in concentration from 2-5 percent in the case of anthracene in polystyrene and from 2-4 percent in the case of *p*-terphenyl in polystyrene have within the experimental errors no significant effect on the saturation of these two scintillators. Also the addition of a small amount of diphenylhexatriene in the *p*-terphenyl in polystyrene did not show definite remarkable influence on the saturation effect observed. The results of Fig. 1 seem to indicate quite clearly that the plastic scintillators show less saturation than the liquid phenylcyclohexane solution. Table I shows that the results of the  $\alpha$ -particle measurements regarding saturation support the conclusions drawn from the investigations with the mesons and protons.

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